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Ikeda

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(54) **NITRIDE SEMICONDUCTOR DEVICE**
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H01L 29/872 (2006.01)
H01L 29/20 (2006.01)

(52) **U.S. Cl.**
CPC **H01L 29/0619** (2013.01); **H01L 29/7786** (2013.01); **H01L 29/872** (2013.01); **H01L 29/2003** (2013.01)

(58) **Field of Classification Search**
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USPC 257/193-194
See application file for complete search history.

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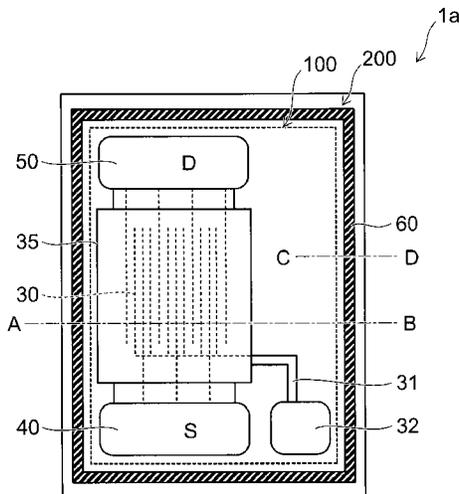
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(57) **ABSTRACT**
According to one embodiment, a nitride semiconductor device including a device region and a guard ring formation region surrounding the device region, the nitride semiconductor device includes a first nitride semiconductor layer provided in the device region and the guard ring formation region; a second nitride semiconductor layer provided on the first nitride semiconductor layer and forming a hetero-junction with the first nitride semiconductor layer; and a shielding layer provided on the second nitride semiconductor layer in the guard ring formation region and electrically protecting the device region. A two-dimensional electron gas is present near an interface between the first nitride semiconductor layer and the second nitride semiconductor layer within the first nitride semiconductor layer below the shielding layer, and the shielding layer is in ohmic contact with the two-dimensional electron gas.

19 Claims, 10 Drawing Sheets



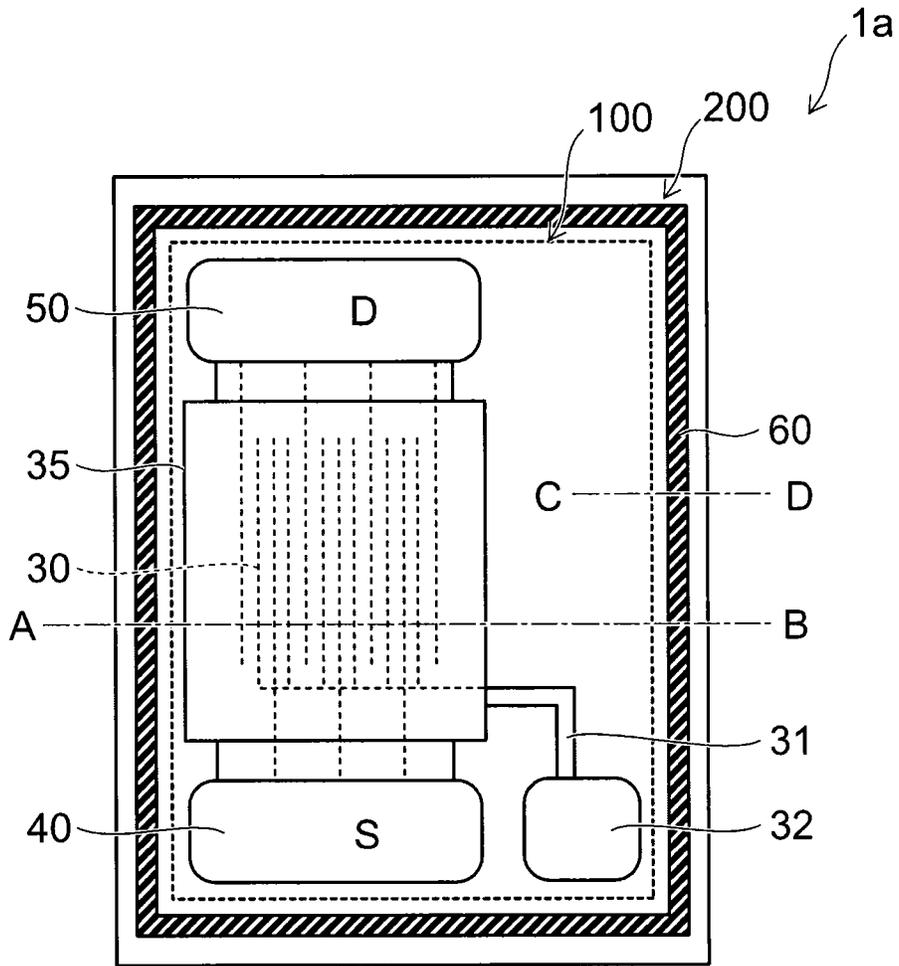


FIG. 1

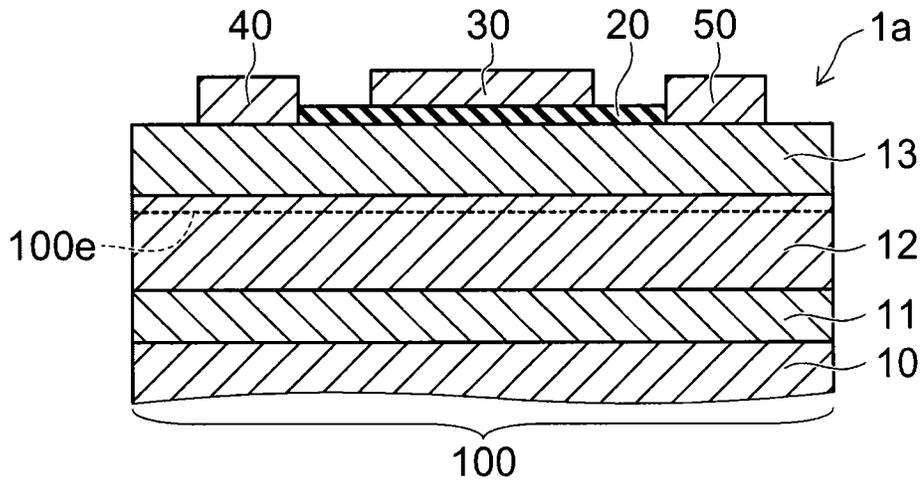


FIG. 2A

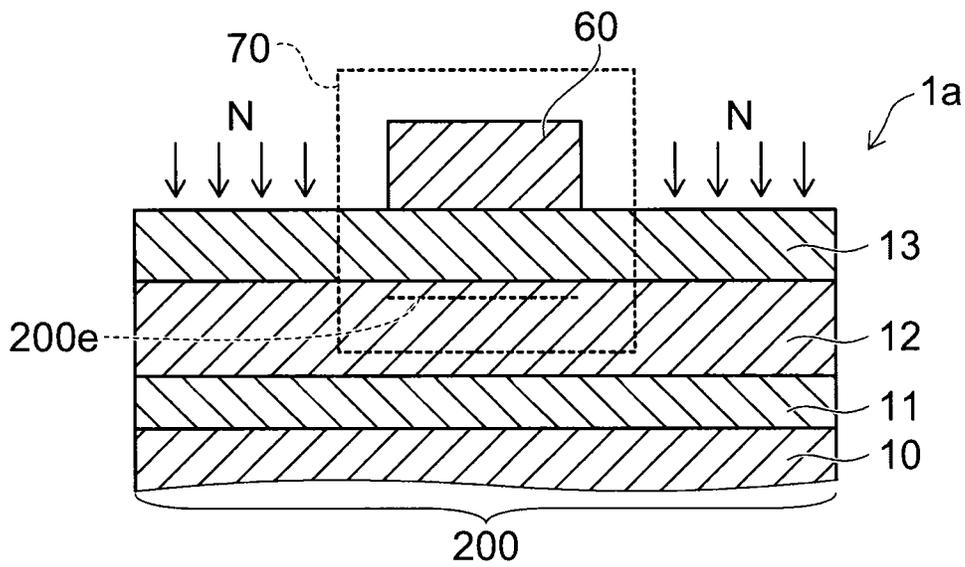


FIG. 2B

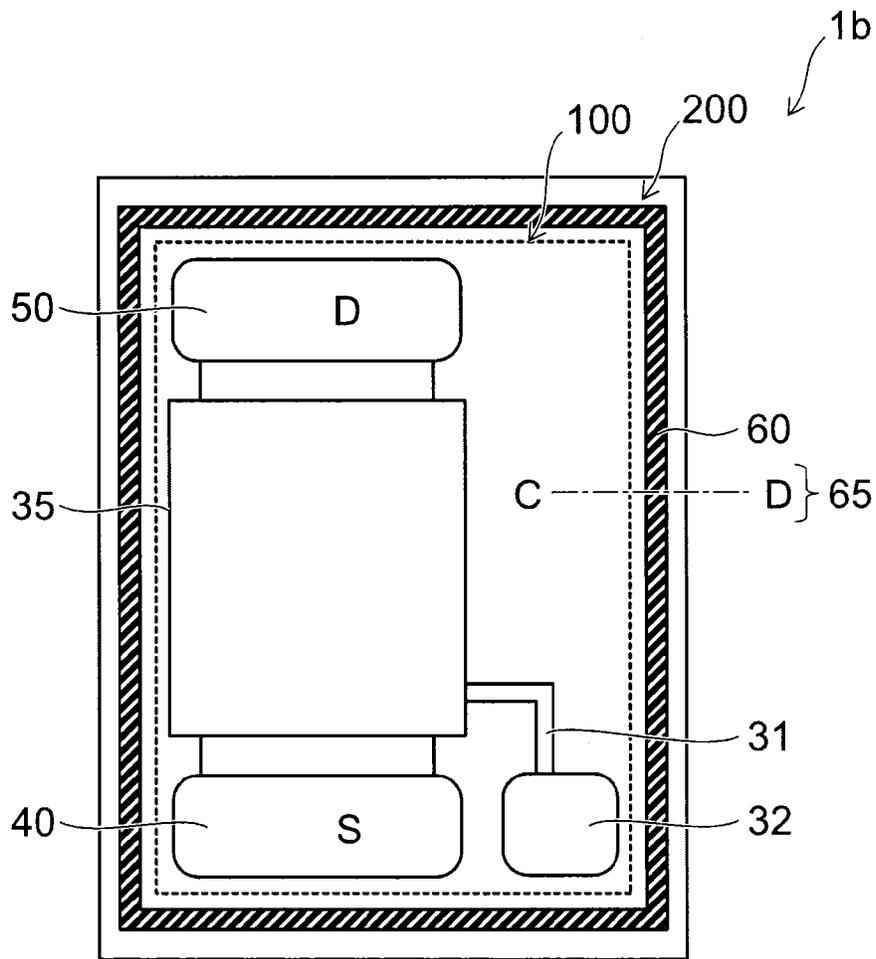


FIG. 3A

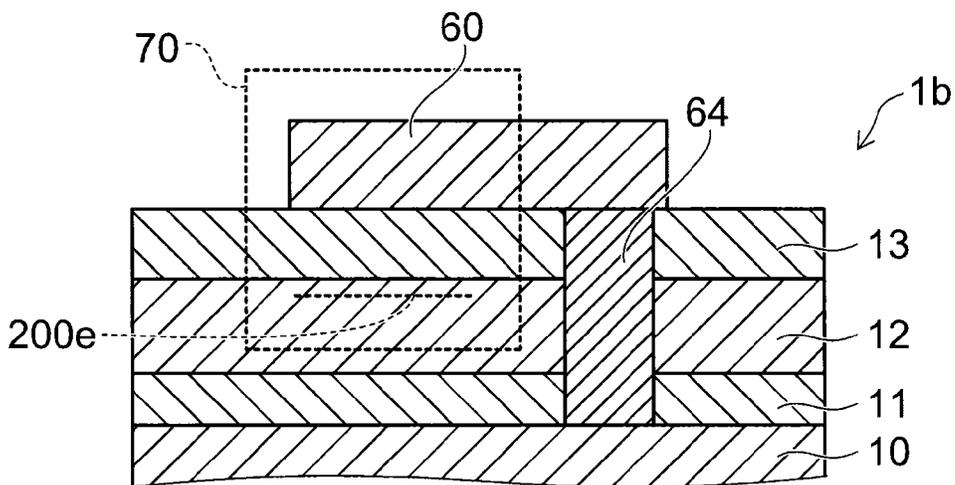


FIG. 3B

FIG. 4

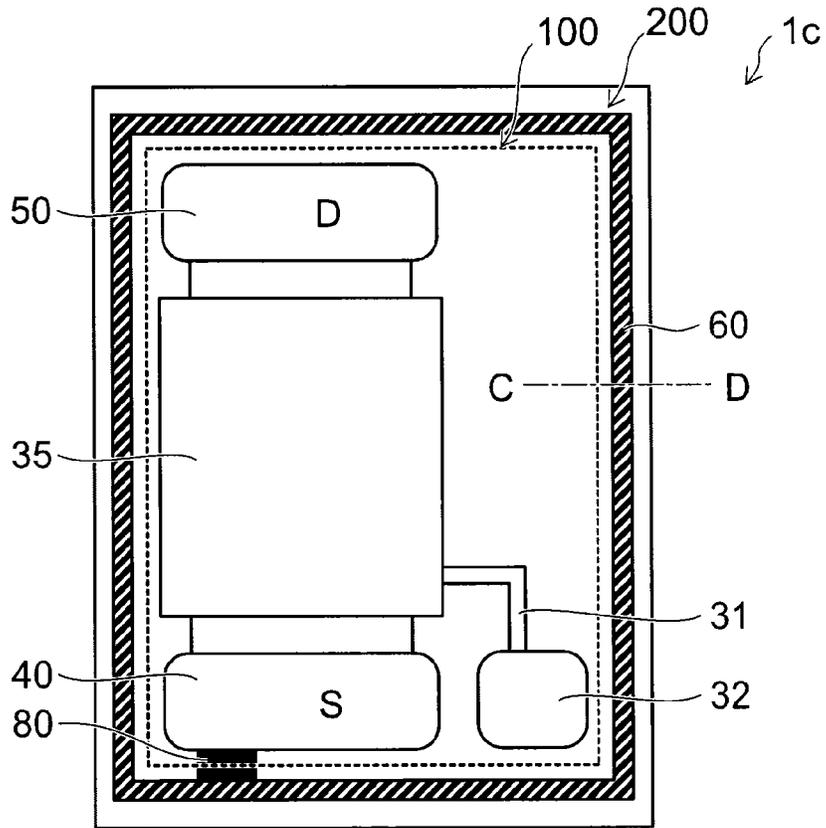
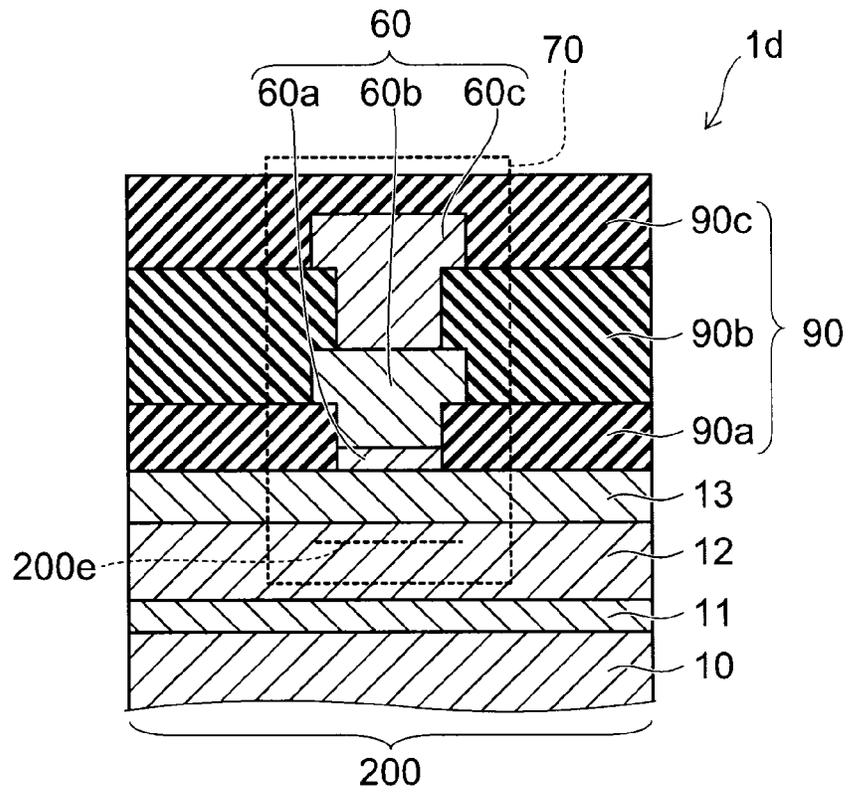


FIG. 5



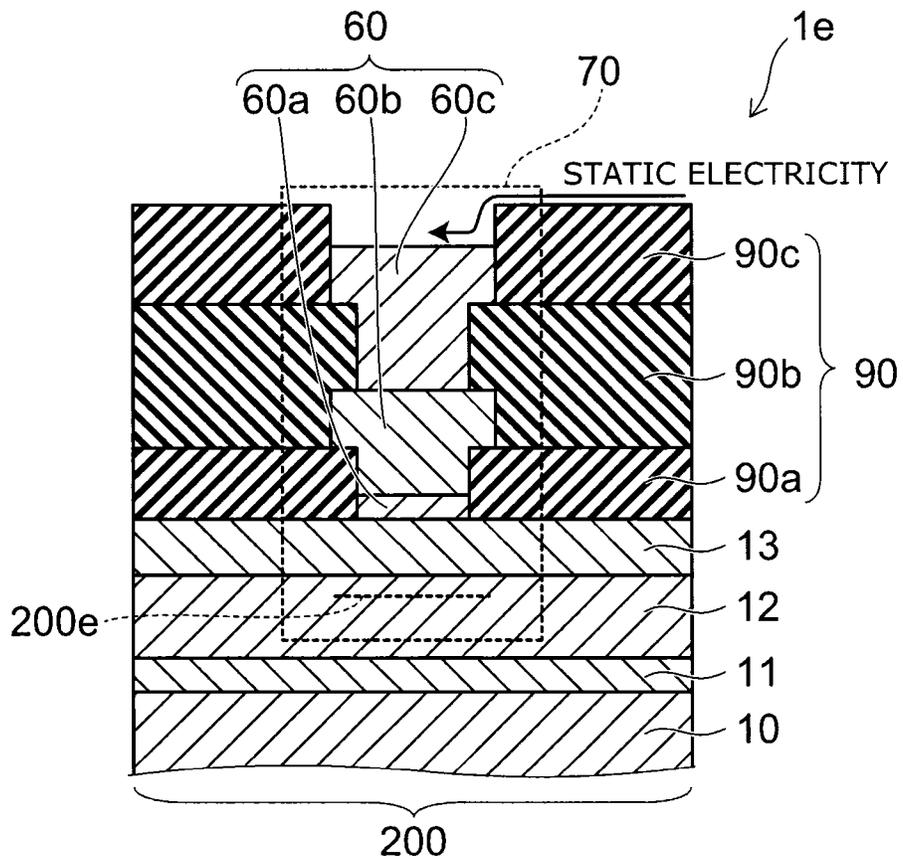


FIG. 6

FIG. 7A

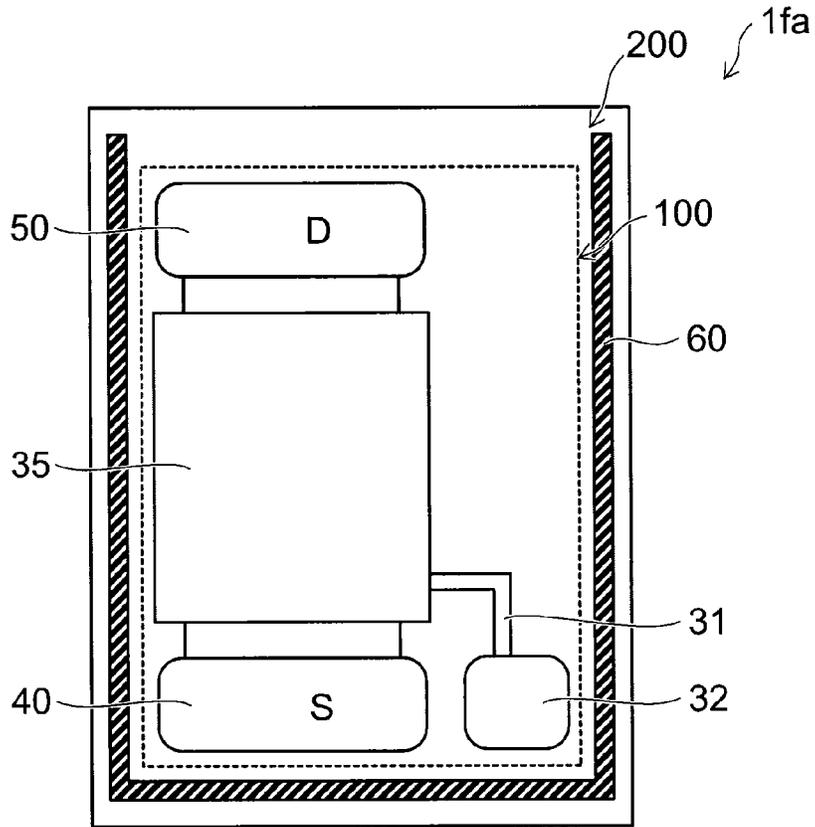


FIG. 7B

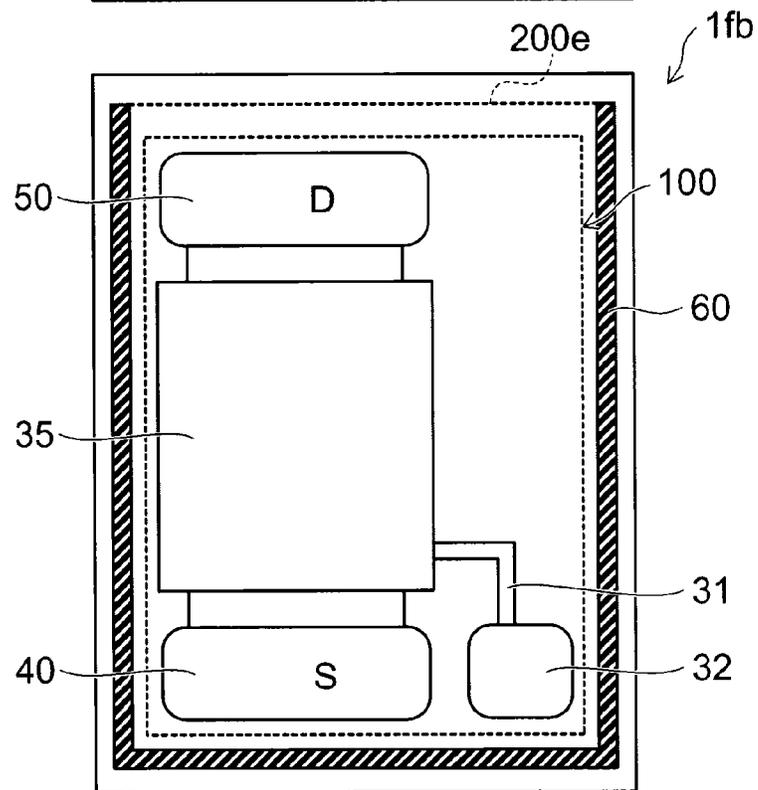


FIG. 8A

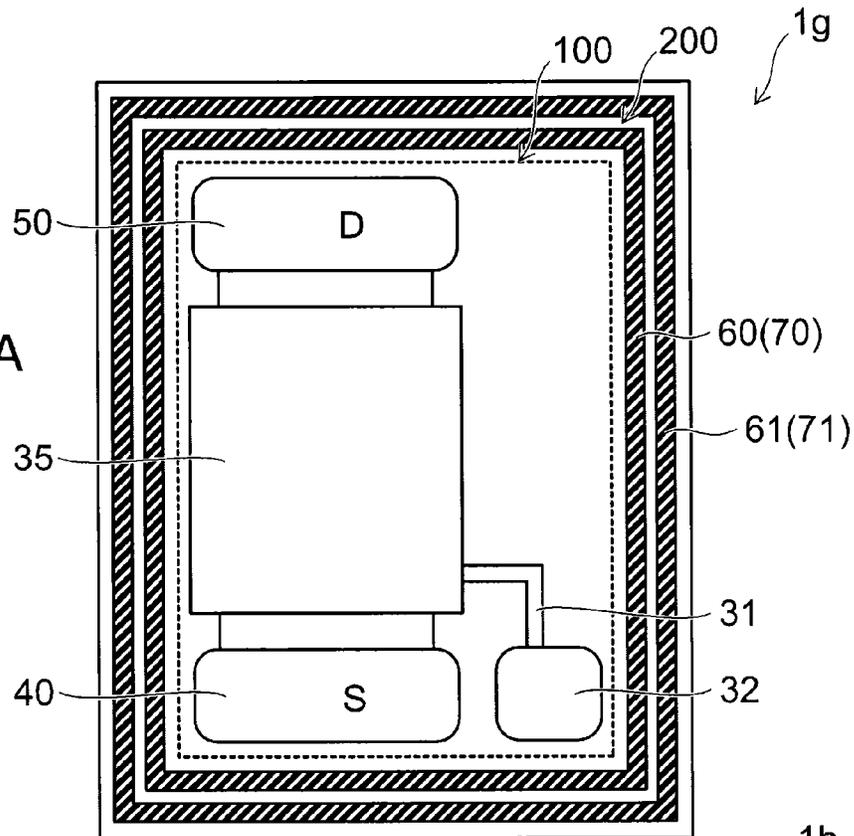
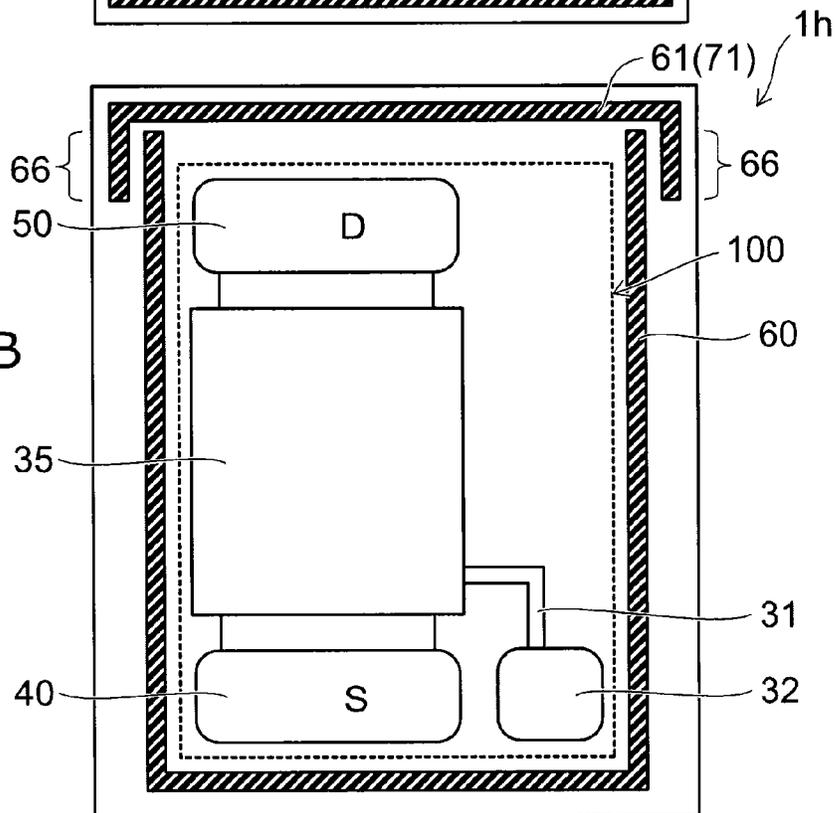


FIG. 8B



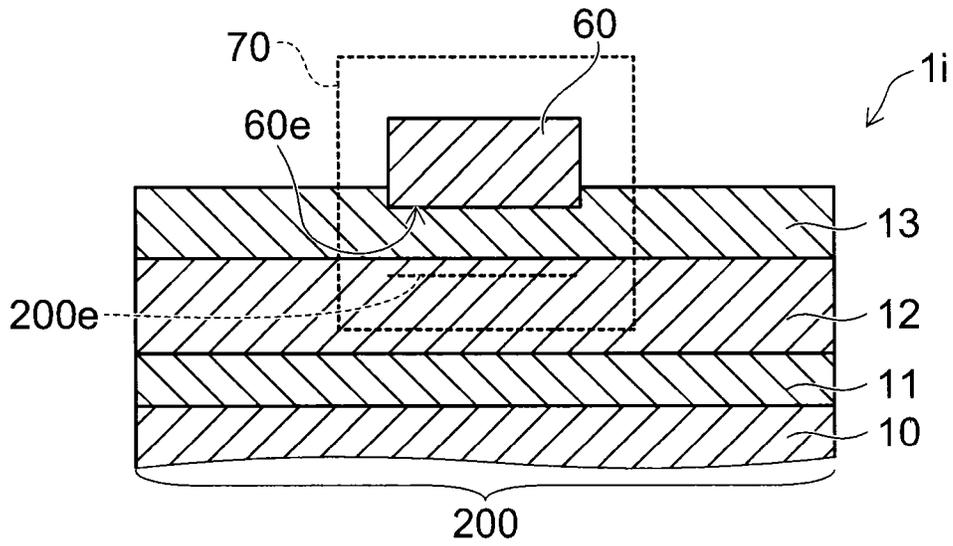


FIG. 9

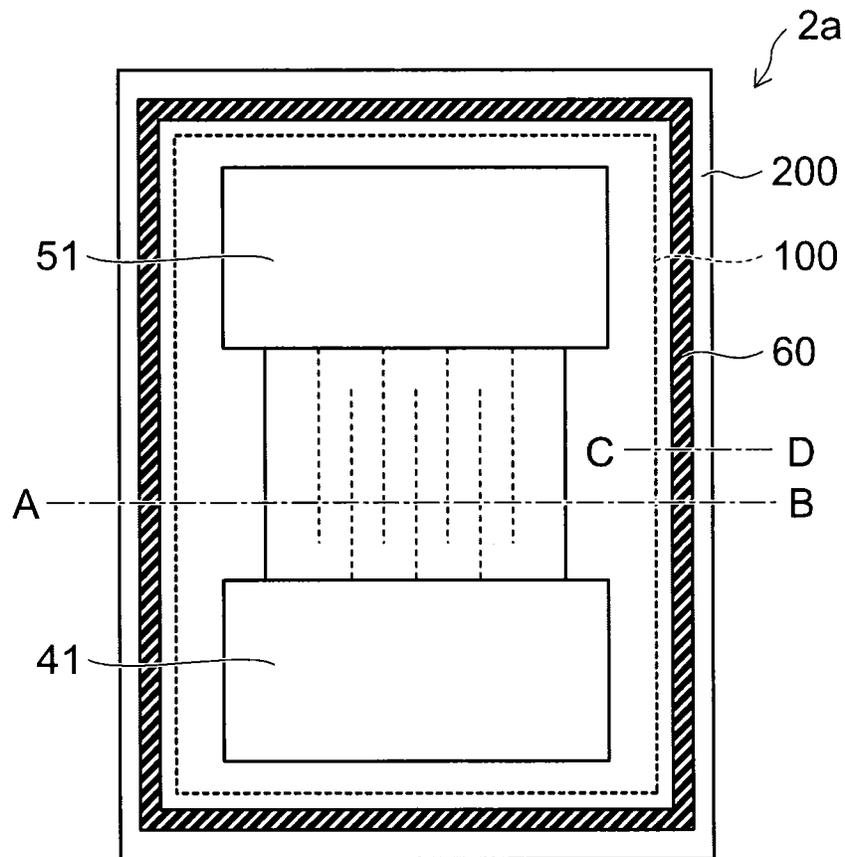


FIG. 10

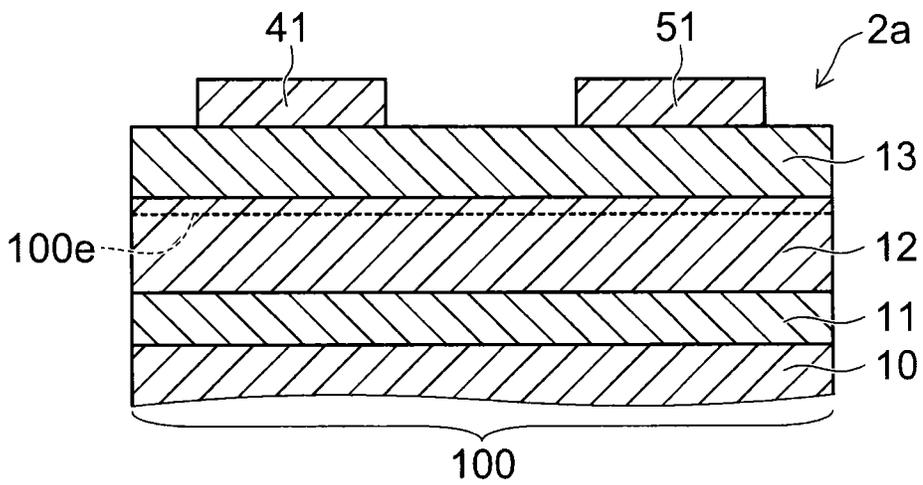


FIG. 11A

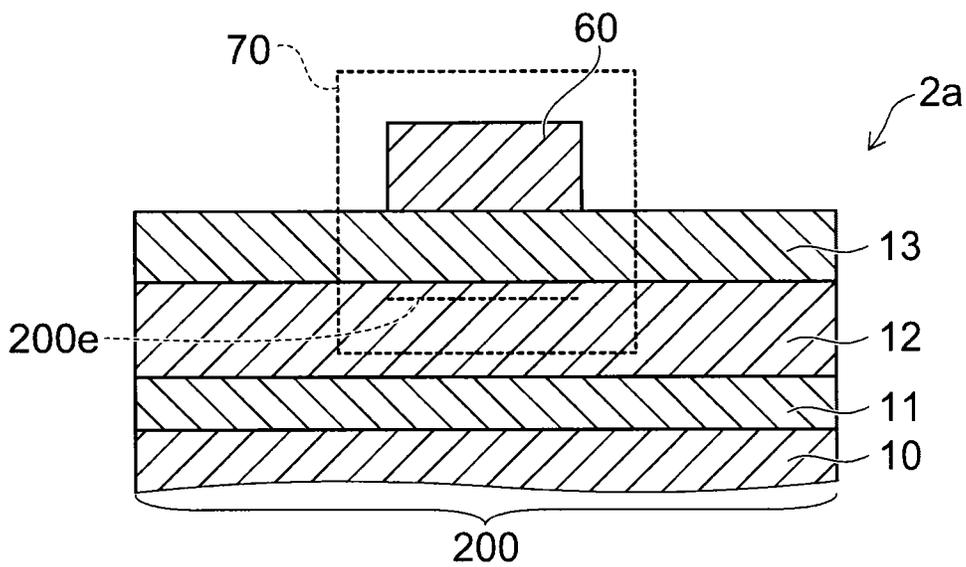


FIG. 11B

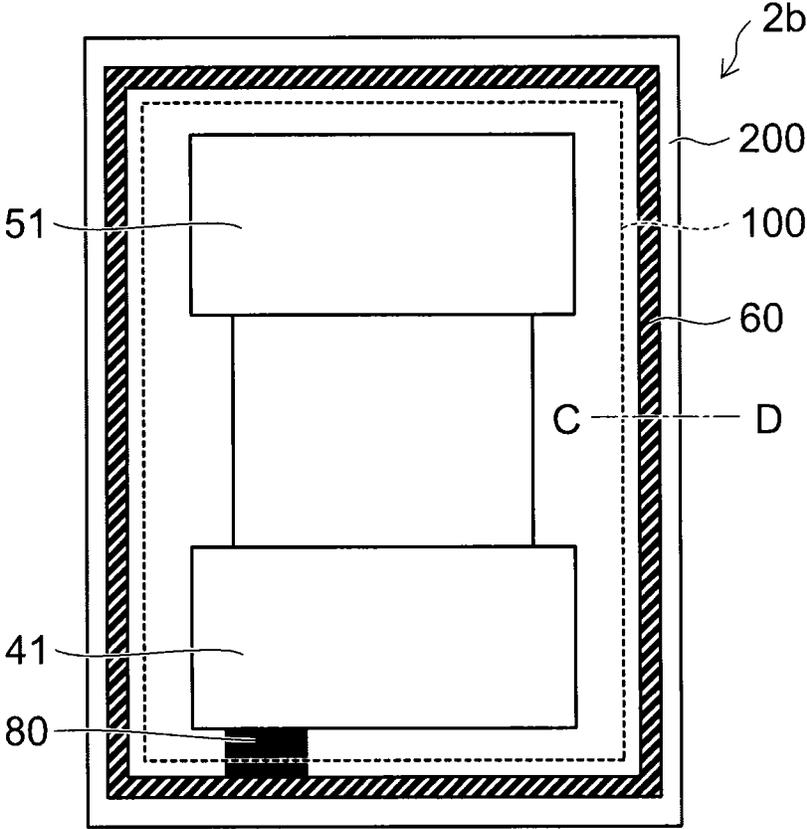


FIG. 12

NITRIDE SEMICONDUCTOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2012-068381, filed on Mar. 23, 2012; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a nitride semiconductor device.

BACKGROUND

A nitride semiconductor has a feature that it has a high breakdown voltage, a low resistance, and a high speed operation in comparison with a silicon semiconductor. For example, in a nitride semiconductor-based transistor having a hetero-structure called a High Electron Mobility Transistor (HEMT), a two-dimensional electron gas is formed in a hetero-junction portion. The two-dimensional electron gas has high electron mobility and a high electron density. Therefore, it is possible to fabricate a device that has a low resistance and a high speed when the nitride semiconductor is used. This enables the device to be downsized and a parasitic capacitance within the device to be reduced. However, when the parasitic capacitance is reduced, there are problems in that static electricity is not absorbed within the device and a resistance of the device against the static electricity is decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic plan view illustrating a nitride semiconductor device according to a first embodiment;

FIGS. 2A and 2B are schematic cross-sectional views illustrating the nitride semiconductor device according to the first embodiment;

FIGS. 3A and 3B are schematic views illustrating a nitride semiconductor device according to a second embodiment;

FIG. 4 is a schematic plan view illustrating a nitride semiconductor device according to a third embodiment;

FIG. 5 is a schematic cross-sectional view illustrating a nitride semiconductor device according to a fourth embodiment;

FIG. 6 is a schematic cross-sectional view illustrating a nitride semiconductor device according to a fifth embodiment;

FIGS. 7A and 7B are schematic plan views illustrating nitride semiconductor devices according to a sixth embodiment;

FIGS. 8A and 8B are schematic plan views illustrating nitride semiconductor devices according to a seventh embodiment;

FIG. 9 is a schematic cross-sectional view illustrating a nitride semiconductor device according to an eighth embodiment;

FIG. 10 is a schematic plan view illustrating a nitride semiconductor device according to a ninth embodiment;

FIGS. 11A and 11B are schematic cross-sectional views illustrating the nitride semiconductor device according to the ninth embodiment; and

FIG. 12 is a schematic plan view illustrating a nitride semiconductor device according to a tenth embodiment.

DETAILED DESCRIPTION

In general, according to one embodiment, a nitride semiconductor device including a device region and a guard ring formation region surrounding the device region, the nitride semiconductor device includes a first nitride semiconductor layer provided in the device region and the guard ring formation region; a second nitride semiconductor layer provided on the first nitride semiconductor layer and forming a hetero-junction with the first nitride semiconductor layer; and a shielding layer provided on the second nitride semiconductor layer in the guard ring formation region and electrically protecting the device region. A two-dimensional electron gas is present near an interface between the first nitride semiconductor layer and the second nitride semiconductor layer within the first nitride semiconductor layer below the shielding layer, and the shielding layer is in ohmic contact with the two-dimensional electron gas.

Hereinafter, embodiments will be described with reference to drawings. In the description below, the same components are denoted with the same symbols, and the repeated explanation of the components that have already been described is appropriately omitted.

First Embodiment

FIG. 1 is a schematic plan view illustrating a nitride semiconductor device according to a first embodiment.

FIGS. 2A and 2B are schematic cross-sectional views illustrating the nitride semiconductor device according to the first embodiment, wherein FIG. 2A is a schematic cross-sectional view in an A-B position of FIG. 1, and FIG. 2B is a schematic cross-sectional view in a C-D position of FIG. 1. In addition, in FIG. 2A, a set of a source, a drain, and a gate is only shown in the A-B cross-section (this is also the same as the A-B cross-section of other transistors).

A nitride semiconductor device **1a** shown in FIG. 1 and FIGS. 2A and 2B is an HEMT. The nitride semiconductor device **1a** has a device region **100**, and a guard ring formation region **200** provided around the device region **100** and surrounding the device region **100**. The nitride semiconductor device includes a substrate **10** provided in the device region **100** and the guard ring formation region **200**, and a buffer layer **11** provided on the substrate **10**. The source, the gate, and the drain that form the transistor are formed in the device region **100**. The guard ring formation region **200** electrically protects the device region **100** and a periphery of the device region. In addition, the nitride semiconductor device **1a** includes a GaN-containing layer (first nitride semiconductor layer) disposed in the device region **100** and the guard ring formation region **200**, and a barrier layer (second nitride semiconductor layer) **13** provided on the GaN-containing layer **12** and forms a hetero-junction with the GaN-containing layer **12**.

The device region **100** shown in FIG. 2A will be described. In the device region **100**, a Two Dimensional Electron Gas (2DEG) **100e** is generated in the vicinity of an interface between the GaN-containing layer **12** and the barrier layer **13** within the GaN-containing layer **12**. The 2DEG has high electron mobility and a high electron density. The GaN-containing layer **12** functions as a carrier running layer.

A gate insulating film **20** is provided on the barrier layer **13**. A gate electrode **30** is provided on the gate insulating film **20**. The gate electrode **30** controls a current flowing between source and drain electrodes. The gate electrode **30** is connected to a gate interconnection **31** in the device region **100**, and the gate interconnection **31** is also connected to a gate

electrode pad **32**. In addition, a source electrode **40** in ohmic contact with the barrier layer **13** and a drain electrode **50** in ohmic contact with the barrier layer **13** are provided in the device region **100**.

The guard ring formation region **200** shown in FIG. 2B will be described.

A shielding layer **60** electrically protecting the device region **100** is provided on the GaN-containing layer **12** in the guard ring formation region **200**. The shielding layer **60** is in ohmic contact with the barrier layer **13**. A 2DEG **200e** is present in the vicinity of an interface between the GaN-containing layer **12** and the barrier layer **13** within the GaN-containing layer **12** below the shielding layer **60**. The shielding layer **60** is in ohmic contact with the 2DEG **200e**. That is, the shielding layer **60** and the 2DEG **200e** are electrically connected. The shielding layer **60** and the 2DEG **200e** are used as a guard ring **70**. In the nitride semiconductor device **1a**, the device region **100** is surrounded by the guard ring **70**.

In the guard ring formation region **200**, the 2DEG **200e** is broken and is not present within the GaN-containing layer **12** other than the GaN-containing layer just below the shielding layer **60**. For example, nitrogen (N), argon (Ar), boron (B), iron (Fe), carbon (C), phosphorus (P), or the like is introduced in the vicinity of the interface between the GaN-containing layer **12** and the barrier layer **13** in portions other than the portion just below the shielding layer **60**, and the 2DEG **200e** is thus suppressed from being generated. The introduction of these elements is carried out, for example, by ion implantation.

Regions in which the 2DEGs **100e** and **200e** are not formed are referred to as isolation regions in a plane of the nitride semiconductor device **1a**. In addition, a region surrounded by the reference numeral **35** is referred to as an FET active region **35**.

The substrate **10** is any one of an Si substrate, an SiC substrate, and a sapphire substrate. The buffer layer **11** includes GaN or AlGaIn. The barrier layer **13** includes non-doped or n-type $\text{Al}_x\text{Ga}_{1-x}\text{N}$ ($0 < X \leq 1$) or $\text{In}_y\text{Al}_{1-y}\text{N}$ ($0 < Y \leq 1$).

A material of the gate insulating film **20** is any one of a silicon nitride film (Si_3N_4), a silicon oxide film (SiO_2), and an aluminum oxide (Al_2O_3). The gate electrode **30** may have a Metal-Insulator-Semiconductor (MIS) structure as shown in the drawing, or may be formed of a material forming a Schottky junction with the barrier layer **13** without the gate insulating film **20**. The source electrode **40** and the drain electrode **50** include, for example, Ti, Al, or the like. A material of the shielding layer **60** may be the same as the material of the source and drain electrodes. This causes a dedicated manufacturing process forming the shielding layer **60** to be unnecessary, so that the number of the manufacturing processes is not increased.

Operations of the nitride semiconductor device **1a** will be described.

A plane size of the nitride semiconductor device **1a** is, for example, 1 square mm. The nitride semiconductor device **1a** is formed by separately cutting out each of a plurality of the nitride semiconductor devices **1a** formed on a surface of a semiconductor wafer in a dicing process. After the cutting out is carried out, the individual nitride semiconductor devices **1a** may be carried by a pickup or the like. In the dicing process and the carrying process, static electricity (static charges) may enter from a side surface of the nitride semiconductor device **1a**.

In the nitride semiconductor device **1a**, the shielding layer **60** in the guard ring **70** shields the static electricity even when the static electricity enters from the side surface of the nitride

semiconductor device **1a**. This enables the device surface inside from the shielding layer **60** to be reliably protected from the static electricity.

In addition, in the nitride semiconductor device **1a**, the 2DEG **200e** below the shielding layer **60** functions as a part of the guard ring **70**. This enables the 2DEG **200e** in the guard ring **70** to shield the static electricity even when the static electricity enters from the side surface of the nitride semiconductor device **1a**. Therefore, the nitride semiconductor layer inside from the 2DEG **200e** is reliably protected from the static electricity.

For example, a height of the 2DEG **100e** from the substrate **10** in the device region **100** is the same as a height of the 2DEG **200e** from the substrate **10** in the guard ring formation region **200**. Therefore, the hetero-junction surface of the device region **100** is reliably protected from the static electricity by the 2DEG **200e**.

In this manner, a potential inside the guard ring **70** becomes equipotential even when the static electricity enters from the side surface of the nitride semiconductor device **1a**, and the electrostatic discharge failure of the device region **100** can thus be prevented from occurring in advance.

In addition, in the nitride semiconductor device **1a**, the shielding layer **60** and the 2DEG **200e** are used as the guard ring **70**, and an effect (shielding range) of shielding the static electricity is thus further increased in comparison with a method of using only the shielding layer **60** as the guard ring.

In addition, in the nitride semiconductor device **1a**, since the shielding layer **60** and the 2DEG **200e** are electrically connected, it is not necessary to bury the shielding layer **60** up to the hetero-junction surface.

In a hetero-structure such as a GaN-based or InAlN-based hetero-structure, in a case of a material with which it is difficult to freely form a p-type semiconductor, a permissible amount against a transient overvoltage called avalanche resistance is small, a parasitic capacitance is small, and a permissible amount against the static electricity is more and more decreased. In particular, the small parasitic capacitance causes the permissible amount against the static electricity of the gate to be decreased and also causes formation of a diode for protecting the gate used often in an Si-based transistor to be difficult in the hetero-structure such as the GaN-based or InAlN-based structure, and an impact on the gate reliability due to the static electricity thus becomes outstanding. As a countermeasure against this, the device may be designed so as to increase the parasitic capacitance of the transistor or the diode. However, there is a problem that a high speed operation can not be realized.

On the other hand, in the first embodiment, the nitride semiconductor device **1a** is realized by suppressing the parasitic capacitance from being increased, enabling the high speed operation, and thus having a high resistance against the static electricity.

Second Embodiment

FIGS. 3A and 3B are schematic views illustrating a nitride semiconductor device according to a second embodiment, wherein FIG. 3A is a schematic plan view, and FIG. 3B is a schematic cross-sectional view in a C-D position of FIG. 3A.

A nitride semiconductor device **1b** shown in FIGS. 3A and 3B is an HEMT. In the nitride semiconductor device **1b**, a conductive substrate is used as a substrate **10** supporting a GaN-containing layer **12**. That is, a mother substrate of an epitaxial substrate for forming the nitride semiconductor device is a conductive substrate. The conductive substrate is,

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for example, an Si substrate, an SIC substrate, or the like. A potential of the substrate **10** may be a ground potential.

In addition, the nitride semiconductor device **1b** includes a via **64** in which a shielding layer **60** is provided within a buffer layer **11**, within the GaN-containing layer **12**, and within a barrier layer **13**. In the nitride semiconductor device **1b**, the shielding layer **60** is electrically connected to the substrate **10** through the via **64** in which the shielding layer **60** is provided within the buffer layer **11**, within the GaN-containing layer **12**, and within the barrier layer **13**. The via **64** may be provided in an entire area below the shielding layer **60**, or may be provided in a part of the area below the shielding layer **60**, that is, only in a region **65** shown in the drawing. In other words, the via **64** is provided below at least a part of the shielding layer **60**. In addition, when the via **64** is disposed in the part of the area below the shielding layer **60**, the via is not limited to only the region **65** shown in the drawing, and may be disposed in any position below the shielding layer **60**.

In addition, since a 2DEG **200e** is electrically connected to the shielding layer **60**, the 2DEG **200e** is also electrically connected to the substrate **10** through the via **64** provided within the buffer layer **11**, within the GaN-containing layer **12**, and within the barrier layer **13**.

According to the nitride semiconductor device **1b**, a side surface (guard ring **70** or via **64**) and a bottom surface (substrate **10**) of the nitride semiconductor device **1b** become equipotential. The guard ring **70** and the substrate **10** shield the static electricity even when the static electricity enters from the side surface and the bottom surface of the nitride semiconductor device **1b**. Therefore, an effect of shielding the static electricity in the nitride semiconductor device **1b** is further enhanced in comparison with the nitride semiconductor device **1a**.

Third Embodiment

FIG. **4** is a schematic plan view illustrating a nitride semiconductor device according to a third embodiment.

A nitride semiconductor device **1c** shown in FIG. **4** is an HEMT. In the nitride semiconductor device **1c**, a shielding layer **60** penetrates an interconnection **80** to be electrically connected to a source electrode **40**.

According to the nitride semiconductor device **1c**, a guard ring **70** and a transistor become equipotential. This enables a device region **100** to be protected from accumulated charges occurring in the process of manufacturing the nitride semiconductor device, which is known as an antenna effect. A position in which the interconnection **80** is disposed is not limited to the position shown.

Fourth Embodiment

FIG. **5** is a schematic cross-sectional view illustrating a nitride semiconductor device according to a fourth embodiment.

In FIG. **5**, a cross-section of a nitride semiconductor device **1d** in the guard ring formation region **200** is shown. The nitride semiconductor device **1d** shown in FIG. **5** is an HEMT.

In the nitride semiconductor device **1d**, a shielding layer **60** has a three-layer structure. The shielding layer **60** has a stacked structure in which a contact layer **60a**, an intermediate layer **60b**, and a top layer **60c** are stacked from a surface of a substrate **10**. The contact layer **60a** is a stacked film in which, for example, Ti and Al are sequentially stacked from the surface of the substrate **10**. The intermediate layer **60b** includes, for example, Au, Al, Cu, or the like. The top layer **60c** includes, for example, Au, Al, Cu, or the like.

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In addition, the nitride semiconductor device **1d** further includes an insulating film **90** covering the shielding layer **60**. The insulating film **90** includes, for example, SiO₂. The insulating film **90** has a stacked structure in which a first insulating film **90a**, a second insulating film **90b**, and a third insulating film **90c** are stacked from the surface of the substrate **10**.

After the nitride semiconductor device **1d** shown in FIG. **5** is manufactured, a wire bonding process may be carried out on the nitride semiconductor device **1d**. In the wire bonding process, a bonding wire is connected to, for example, an electrode outside a package or the like from the electrode of the transistor.

When the insulating film **90** covering the shielding layer **60** is not provided, discharge may occur between the bonding wire and the shielding layer **60** in the wire bonding process. According to the nitride semiconductor device **1d**, since the shielding layer **60** is covered by the insulating film **90**, the discharge can be prevented from occurring in advance. Therefore, the reliability of the nitride semiconductor device **1d** after the wire bonding process is enhanced.

Fifth Embodiment

FIG. **6** is a schematic cross-sectional view illustrating a nitride semiconductor device according to a fifth embodiment.

A cross-section of a nitride semiconductor device **1e** in a guard ring formation region **200** is shown in FIG. **6**. The nitride semiconductor device **1e** shown in FIG. **6** is an HEMT. In the nitride semiconductor device **1e**, at least a part of a surface (surface of a top layer **60c**) of a shielding layer **60** is exposed from an insulating film **90**.

According to the nitride semiconductor device **1e**, static electricity is made to pass through the guard ring **70** in advance even when the static electricity enters a device region **100** along a surface of the insulating film **90**. When the static electricity reaches the guard ring **70**, the static electricity is shielded by the guard ring **70**. Therefore, the device region **100** is reliably protected from the static electricity in the nitride semiconductor device **1e**.

Sixth Embodiment

FIGS. **7A** and **7B** are schematic plan views illustrating nitride semiconductor devices according to a sixth embodiment, wherein FIG. **7A** is a schematic plan view illustrating a first example of the sixth embodiment, and FIG. **7B** is a schematic plan view illustrating a second example of the sixth embodiment. Nitride semiconductor devices **1fa** and **1fb** shown in FIGS. **7A** and **7B** are HEMTs.

In the nitride semiconductor device **1fa** shown in FIG. **7A**, a part of a shielding layer **60** is cut to be noncontiguous. In addition, a 2DEG is not present below a portion in which the part of the shielding layer **60** is noncontiguous. That is, in the nitride semiconductor device **1fa**, the part of the shielding layer **60** and the part of the 2DEG are noncontiguous, and a part of a guard ring **70** becomes noncontiguous.

As described above, in the wiring bonding process, the discharge may occur between the bonding wire and the guard ring **70**. In the nitride semiconductor device **1fa**, the guard ring **70** is made to avoid the position in which danger such as the discharge is likely to occur and is disposed in a portion other than the position in which the guard ring is removed. Accordingly, danger such as the discharge is avoided and the shielding effect on the static electricity is maintained.

For example, in the nitride semiconductor device **1fa**, the guard ring **70** is not disposed near an electrode such as a drain

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electrode **50** to which a high voltage is applied, and the guard ring **70** is disposed near a source electrode to which a low voltage is applied in comparison with the drain electrode **50**. Therefore, it is possible to avoid an electric short between the electrode to which the high voltage is applied and the guard ring **70** and also to reliably protect a device region **100** from the static electricity.

In addition, in the nitride semiconductor device **1f** shown in FIG. **7B**, only the part of a shielding layer **60** is noncontiguous, and a 2DEG **200e** remains below the noncontiguous part. Such structure is also included in the embodiment.

In this case, the danger such as the discharge described above is avoided and a shielding effect on the static electricity is maintained by the 2DEG **200e**.

Seventh Embodiment

FIGS. **8A** and **8B** are schematic plan views illustrating nitride semiconductor devices according to a seventh embodiment, wherein FIG. **8A** is a schematic plan view showing a state in which a shielding layer is multiply disposed, and FIG. **8B** is a schematic plan view showing a state in which a part of a shielding layer in FIG. **8A** becomes noncontiguous.

Nitride semiconductor devices **1g** and **1h** shown in FIGS. **8A** and **8B** are HEMTs.

The nitride semiconductor device **1g** shown in FIG. **8A** further includes another shielding layer **61** from a shielding layer **60** in a guard ring formation region **200**. The shielding layer **61** is provided in the guard ring formation region **200** that is an opposite side of the device region **100** of the shielding layer **60**. The shielding layer **60** is surrounded by the shielding layer **61**. The shielding layer **61** is in ohmic contact with the barrier layer **13**.

A 2DEG is present near an interface between the GaN-containing layer **12** and the barrier layer **13** within the GaN-containing layer **12** below the shielding layer **61**. The shielding layer **61** is in ohmic contact with the 2DEG. The shielding layer **61** and the 2DEG are used as a guard ring **71**. The guard ring **71** surrounds the guard ring **70**. That is, when the nitride semiconductor device **1g** is seen from a direction perpendicular to a main surface of the substrate **10**, the shielding layer **60** is surrounded by the shielding layer **61** and the 2DEG present below the shielding layer **61**. In addition, the guard rings are disposed doubly in a guard ring formation region **200**. The number of the guard rings to be disposed in the guard ring formation region **200** is not limited to the number shown in the drawing, and may be three or more.

According to the nitride semiconductor device **1g**, the guard rings are multiply disposed and thus a device region can be reliably protected from static electricity.

In the nitride semiconductor device **1h** shown in FIG. **8B**, a part of each of guard rings **70** and **71** is cut and noncontiguous. In FIG. **8B**, a state in which a part of a shielding layer **60** and a part of the shielding layer **61** are noncontiguous is shown. When the part of the shielding layer **61** is noncontiguous, a part of the 2DEG below the part of the shielding layer may be noncontiguous.

When a range in which the guard ring **70** and the guard ring **71** overlap each other is a range **66**, the shielding layer **61** in the range **66** is provided in the guard ring formation region **200** that is an opposite side of the device region **100** of the shielding layer **60**. That is, in the guard ring formation region **200**, at least a part of the shielding layer **61** is provided on an opposite side of at least a part of the shielding layer **60**.

As described above, in the wire bonding process, the discharge between the bonding wire and the guard ring **70** may

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occur. In the nitride semiconductor device **1h**, the guard rings **70** and **71** are not disposed in the position in which danger such as the discharge is likely to occur while the shielding effect on the static electricity is maintained by the guard rings **70** and **71** in a portion other than the position in which the guard rings are not disposed.

In addition, in the nitride semiconductor device **1h**, the guard rings are not disposed doubly in the portion other than the range **66**. Therefore, the parasitic capacitance between electrodes of the transistor caused by the disposed guard ring is reduced in comparison with the nitride semiconductor device **1g**.

In addition, in the nitride semiconductor device **1h**, the guard ring **71** is disposed near the electrode such as a drain electrode **50** to which a high voltage is applied, and the guard ring **70** is disposed near a source electrode to which a low voltage is applied in comparison with the drain electrode **50**. That is, the guard rings are divided and disposed near the electrode to which the high voltage is applied and near the electrode to which the low voltage is applied.

Since the guard ring **71** is disposed outward farther than the guard ring **70**, a distance between the drain electrode **50** and the guard ring **71** is longer than a distance between the source electrode **40** and the guard ring **70**. This enables the electric short between the electrode to which the high voltage is applied and the guard ring **70** to be avoided and also enables the device region **100** to be reliably protected from the static electricity.

Eighth Embodiment

FIG. **9** is a schematic cross-sectional view illustrating a nitride semiconductor device according to an eighth embodiment.

In FIG. **9**, the cross-section of a nitride semiconductor device **1i** in a guard ring formation region **200** is shown.

In the nitride semiconductor device **1i**, the lower end **60e** of the shielding layer **60** protrudes from a surface of a barrier layer **13** to an inside of the barrier layer. In other words, the lower end **60e** of the shielding layer **60** is positioned to be lower than the surface of the barrier layer **13**. Accordingly, the ohmic contact between the shielding layer **60** and a 2DEG **200e** becomes further enhanced, and the electrical connection between the shielding layer **60** and the 2DEG becomes stronger. Therefore, the static electricity is more reliably shielded by a guard ring **70**.

Ninth Embodiment

FIG. **10** is a schematic plan view illustrating a nitride semiconductor device according to a ninth embodiment.

FIGS. **11A** and **11B** are schematic cross-sectional views illustrating the nitride semiconductor device according to the ninth embodiment, wherein FIG. **11A** is a schematic cross-sectional view in the A-B position of FIG. **10**, and FIG. **11B** is a schematic cross-sectional view in the C-D position of FIG. **10**. In addition, only a set of an anode and a cathode in the A-B cross-section of FIG. **10** is shown in FIG. **11A**.

A nitride semiconductor device **2a** shown in FIG. **10** and FIGS. **11A** and **11B** are a schottky diode. The nitride semiconductor device **2a** has a device region **100**, and a guard ring formation region **200** provided around the device region **100** and surrounding the device region **100**. The nitride semiconductor device **2a** includes a substrate **10** provided in the device region **100** and the guard ring formation region **200**, and a buffer layer **11** provided on the substrate **10**. In addition, the nitride semiconductor device **2a** includes a GaN-contain-

ing layer 12 disposed in the device region 100 and the guard ring formation region 200, and a barrier layer 13 provided on the GaN-containing layer 12 and forming a hetero-junction with the GaN-containing layer 12.

The device region 100 shown in FIG. 11A will be described.

In the device region 100, a 2DEG 100e occurs in the vicinity of the interface between the GaN-containing layer 12 and the barrier layer 13 within the GaN-containing layer 12.

In the device region 100, an anode electrode 41 in schottky contact with the barrier layer 13, and a cathode electrode 51 in ohmic contact with the barrier layer 13 are provided.

The guard ring formation region 200 shown in FIG. 11B will be described.

In the guard ring formation region 200, a shielding layer 60 electrically protecting the device region 100 is provided on the GaN-containing layer 12. The shielding layer 60 is in ohmic contact with the barrier layer 13. A 2DEG 200e is present in the vicinity of the interface between the GaN-containing layer 12 and the barrier layer 13 within the GaN-containing layer 12 below the shielding layer 60. The shielding layer 60 is in ohmic contact with the 2DEG 200e.

That is, the shielding layer 60 and the 2DEG 200e are electrically connected. The shielding layer 60 and the 2DEG 200e are used as the guard ring 70. In the nitride semiconductor device 2a, the device region 100 is surrounded by the guard ring 70. As described above, in the guard ring formation region 200, the 2DEG 200e is destroyed to be absent within the GaN-containing layer 12 other than the GaN-containing layer just below the shielding layer 60.

The anode electrode 41 includes Ni, Au, Pt, Pd, or the like. The cathode electrode 51 includes, for example, Ti, Al, or the like. A material of the shielding layer 60 may be the same as the cathode electrode 51. Accordingly, a dedicated manufacturing process is not necessary for the shielding layer 60, and the number of manufacturing processes is not increased.

In the nitride semiconductor device 2a, the shielding layer 60 in the guard ring 70 shields the static electricity even when the static electricity enters from the side surface of the nitride semiconductor device 2a. Therefore, a surface of the device inside from the shielding layer 60 is reliably protected from the static electricity.

In addition, even when the static electricity enters from the side surface of the nitride semiconductor device 2a, the 2DEG 200e in the guard ring 70 shields the static electricity. Therefore, the nitride semiconductor layer inside from the 2DEG 200e is reliably protected from the static electricity. For example, the height of the 2DEG 100e from the substrate 10 in the device region 100 is the same as the height of the 2DEG 200e from the substrate 10 in the guard ring formation region 200. Therefore, the hetero-junction surface of the device region 100 is reliably protected from the static electricity by the 2DEG 200e.

In this manner, even when the static electricity enters from the side surface of the nitride semiconductor device 2a, the potential inside the guard ring 70 becomes equipotential, so that the electrostatic discharge failure on the device region 100 can be prevented from occurring in advance.

In the nitride semiconductor device 2a, since the shielding layer 60 and the 2DEG 200e are used as the guard ring 70, an effect of shielding the static electricity is further enhanced in comparison with the method of using only the shielding layer 60 as the guard ring.

In addition, in the nitride semiconductor device 2a, since the shielding layer 60 and the 2DEG 200e are electrically connected, it is not necessary to bury the shielding layer 60 up to the hetero-junction surface.

In the ninth embodiment, the nitride semiconductor device 2a suppressing the parasitic capacitance from being increased, enabling the high speed operation, and having a high resistance against the static electricity is realized.

Tenth Embodiment

FIG. 12 is a schematic plan view illustrating a nitride semiconductor device according to a tenth embodiment.

A nitride semiconductor device 2b shown in FIG. 12 is a Schottky diode. In the nitride semiconductor device 2b, a shielding layer 60 is electrically connected to an anode electrode 41 through an interconnection 80. The position in which the interconnection 80 is disposed is not limited to the position shown in the drawing.

According to the nitride semiconductor device 2b, a guard ring 70 and the diode become equipotential. This enables a device region 100 to be protected from accumulated charges occurring in the process of manufacturing the nitride semiconductor device, which is known as an antenna effect.

The "nitride semiconductor" in the specification includes semiconductors having all compositions in which each of the composition ratios x, y, and z within the range in the chemical formula of $B_xIn_yAl_zGa_{1-x-y-z}N$ ($0 \leq x \leq 1$, $0 \leq y \leq 1$, $0 \leq z \leq 1$, $x+y+z \leq 1$) is changed. In addition, in the above chemical formula, the composition further including group V elements other than N (nitrogen), the composition further including various elements added to control various physical properties such as a conductivity type, and the composition further including various elements that are included unintentionally are also included in the "nitride semiconductor."

The embodiments have been described with reference to the specific examples. However, the embodiments are not limited to the specific examples. That is, the specific examples to which appropriate design changes are added by those skilled in the art are also included in the range of the embodiments as long as they have the characteristics of the embodiments. Each component included in the specific examples described above and a disposition, a material, a condition, a shape, a size, or the like of the component are not limited to the illustrated examples but may be changed as appropriate.

In addition, each component included in the embodiments described above may be combined as far as it is technically possible, and the combinations thereof are also included in the range of the embodiments as long as they include the characteristics of the embodiments. In addition, it is understood by those skilled in the art that various changes and modifications are possible in the category of the spirit of the embodiments and these changes and modifications are also included in the range of the embodiments.

The embodiments have been described above with reference to examples. However, the embodiments are not limited to these examples. More specifically, these examples can be suitably modified in design by those skilled in the art. Such modifications are also encompassed within the scope of the embodiments as long as they include the features of the embodiments. The components included in the above examples and their layout, material, condition, shape, size and the like are not limited to those illustrated, but can be suitably modified.

Furthermore, the components included in the above embodiments can be combined as long as technically feasible. Such combinations are also encompassed within the scope of the embodiments as long as they include the features of the embodiments. In addition, those skilled in the art can conceive various modifications and variations within the

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spirit of the embodiments. It is understood that such modifications and variations are also encompassed within the scope of the embodiments.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the invention.

What is claimed is:

1. A nitride semiconductor device comprising:
 a device region;
 a guard ring formation region surrounding the device region;
 a first nitride semiconductor layer provided in the device region and the guard ring formation region;
 a second nitride semiconductor layer provided on the first nitride semiconductor layer and forming a hetero junction with the first nitride semiconductor layer;
 a source electrode provided on the second nitride semiconductor layer in the device region;
 a drain electrode provided on the second nitride semiconductor layer in the device region;
 a gate electrode provided on the second nitride semiconductor layer, the gate electrode being provided between the source electrode and the drain electrode; and
 a shielding layer provided on the second nitride semiconductor layer in the guard ring formation region,
 a two-dimensional electron gas being present near an interface between the first nitride semiconductor layer and the second nitride semiconductor layer within the first nitride semiconductor layer below the shielding layer, and
 the shielding layer being in ohmic contact with the two-dimensional electron gas.
2. The device according to claim 1, wherein the device region is surrounded by the shielding layer and the two-dimensional electron gas.
3. The device according to claim 1, further comprising:
 a conductive substrate supporting the first nitride semiconductor layer; and
 a via provided within the first nitride semiconductor layer and within the second nitride semiconductor layer, wherein the shielding layer is electrically connected to the conductive substrate through the via.
4. The device according to claim 3, wherein a potential of the conductive substrate is a ground potential.
5. The device according to claim 3, wherein the via is provided below at least a part of the shielding layer.

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6. The device according to claim 1, wherein the shielding layer is electrically connected to the source electrode.
7. The device according to claim 1, wherein a cathode electrode and an anode electrode are provided on the second nitride semiconductor layer in the device region, and the shielding layer is electrically connected to the anode electrode.
8. The device according to claim 1, further comprising:
 an insulating film covering the shielding layer.
9. The device according to claim 8, wherein at least a part of a surface of the shielding layer is exposed from the insulating film.
10. The device according to claim 1, wherein a part of the shielding layer or a part of the two-dimensional electron gas is noncontiguous.
11. The device according to claim 1, wherein a part of the shielding layer is noncontiguous, and the two-dimensional electron gas is present below the part of the shielding layer.
12. The device according to claim 1, further comprising:
 another shielding layer different from the shielding layer in the guard ring formation region, and
 another two-dimensional electron gas is present near an interface between the first nitride semiconductor layer and the second nitride semiconductor layer within the first nitride semiconductor layer below the another shielding layer,
 wherein the another shielding layer is provided in the guard ring formation region on an opposite side of the device region of the shielding layer and is in ohmic contact with the another two-dimensional electron gas.
13. The device according to claim 12, wherein the shielding layer is surrounded by the another shielding layer.
14. The device according to claim 12, wherein the shielding layer is surrounded by the another shielding layer and the another two-dimensional electron gas.
15. The device according to claim 12, wherein a part of the another shielding layer or a part of the another two-dimensional electron gas is noncontiguous.
16. The device according to claim 12, wherein at least a part of the another shielding layer on an opposite side of at least a part of the shielding layer is provided in the guard ring formation region.
17. The device according to claim 1, wherein a lower end of the shielding layer is positioned on a downside of a surface of the second nitride semiconductor layer.
18. The device according to claim 1, wherein the two-dimensional electron gas is selectively present below the shielding layer.
19. The device according to claim 1, further comprising an isolation region between the device region and the guard ring formation region, the two-dimensional electron gas being present in the device region and below the shielding layer in the guard ring formation region.

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